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Evaluation of Two Station-Based Boarding Systems for Intercity Buses

Prepared for

Transportation Development Centre
Policy and Coordination Group

Transport Canada

by

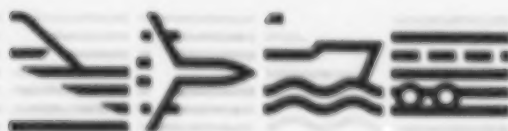
Micheal D. O'Riain Ph.D., P.Eng.

The Rehabilitation Centre, Ottawa
and
University of Ottawa

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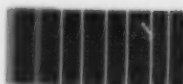
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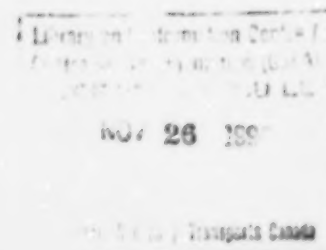
Transport Canada

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**The Rehabilitation Centre, Ottawa
and
University of Ottawa**

October 1990



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The contents of this report reflect the views of the contractor and not necessarily the official views or policies of the Transportation Development Centre, Transport Canada.

Un sommaire en français de ce document est inclus avant la table des matières.

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16. Abstract The purpose of the study was to examine two new methods to enable physically disabled persons to board intercity buses. The two methods are based on a boarding strategy in which a physically disabled client is brought into the bus on a specially designed transfer chair. A level transfer is then made to the bus seat. A key part of this work was the design and construction of the transfer chair, which had to give full support to the client, while being small enough to fit into the bus. Two different boarding systems were developed. One system uses a foldable ramp which is situated along the side of the bus. The transfer chair can be wheeled up the ramp and placed beside the first row of seats. The second system uses an electrically powered stair-lift device which brings the transfer chair right into the bus. Each of the two systems has advantages over the other, and these are discussed fully in the report. Tests were performed to determine the feasibility of the two new bus-boarding systems. The results are reported here and guidelines have been set down for further development. Specifically, the development of a third and portable bus-boarding system is suggested. This system could be stored on a bus, for use as needed.					
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16. Résumé Le but de cette étude était d'examiner deux nouvelles méthodes permettant aux personnes à mobilité réduite de voyager en autocar. Ces deux procédés se fondent sur une stratégie d'embarquement suivant laquelle le voyageur est emmené dans l'autocar à l'aide d'un siège de transfert spécialement conçu. Un transfert de niveau est ensuite opéré entre le siège de transfert et le siège d'autocar. L'élément clef de cette étude a été la conception et la construction du siège de transfert, qui doit maintenir parfaitement le voyageur, tout en étant assez étroit pour entrer dans l'autocar. Deux différents systèmes d'embarquement ont été développés. L'un est une rampe pliante s'allongeant le long du côté de l'entrée de l'autocar; le siège de transfert peut suivre la rampe et être acheminé près de la première rangée de sièges. L'autre consiste en une plateforme notorisée qui transporte le siège de transfert directement dans l'autocar. Chacun des systèmes comporte des avantages par rapport à l'autre; ceux-ci sont traités en détail dans le rapport. Des essais ont été effectués pour déterminer les possibilités de ces deux nouveaux systèmes d'embarquement. Les résultats figurent dans le rapport et des idées directrices ont été notées en vue de développements futurs, surtout en ce qui concerne la proposition du développement d'un troisième système d'embarquement entièrement portatif. Celui-ci pourrait être emmagasiné dans un des compartiments de l'autocar, prêt à être utilisé au besoin.					
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SUMMARY

Transport Canada, as part of its objective to facilitate public transportation for physically disabled persons, has supported work on the development of innovative methods to enable disabled travelers to board intercity buses. This is not an easy problem to solve. Added to the physical limitations of the disabled travelers themselves, are the narrow widths of the entrances and aisles in standard intercity buses. Overcoming the many difficulties presented by this project involved fresh thinking on the problem and the development of innovative ideas.

The major innovation we have made arose from a realization of the following factors:

- i) Boarding a bus by a physically disabled person will involve one or two transfers. For example, a passenger who uses a wheelchair will have to transfer from his or her wheelchair to the boarding system and from the boarding system to a bus seat. People who use wheelchairs are accustomed to making transfers from one chair to another - preferably transferring to a chair at the same height or lower.
- ii) A bus-boarding system that involves a boom or similar device, which reaches through the door to the first row of passenger seats, will likely impede the transfer process.
- iii) An ideal bus-boarding system would enable the first transfer (from the passenger's own wheelchair to the bus-boarding system) to be performed at a convenient location within the bus terminal. The boarding device would then be brought into the bus to the first row of seats, where no additional restrictions would impede the transfer to the bus seat. The implementation of this ideal system started with the design and construction of a transfer chair. Following this, two different systems were designed to bring the transfer chair into the bus and place it beside the first row of passenger seats.

The transfer chair has the following features:

- o The chair is on wheels, enabling it to be moved freely either inside the bus terminal or inside the bus itself. Thus, the transfer from the client's own wheelchair to the transfer chair can be performed at the most convenient location - giving maximum privacy, comfort, convenience, etc.
- o The height of the seat is variable, enabling level transfers (or high-to-low transfers) to be done in all situations. The chair has six caster wheels - two of which are of fixed direction, but removable, and four of which can swivel freely. This gives the chair maximum maneuverability when required and also the ability to be steered when this is needed.
- o To maximize its stability, the chair is made as large as possible within the constraint that it must be compatible with the width of the bus entrance and aisle.

Two different systems to bring the transfer chair into the bus have been designed. The first system uses a foldable ramp, which is placed along the side of the bus. The second system uses a modified stair-lift system with an electric motor to bring the transfer chair up to the level of the bus aisle. Both transfer systems work very well; each has its advantages and disadvantages.

The advantages of the ramp are:

- o The system is totally independent of external power and will work even in a power failure.
- o The ramp system requires just one attendant who is in close proximity to the disabled client at all times.

Disadvantages of the ramp:

- o The system is fairly bulky even when folded up.
- o The attendant will have to be sufficiently fit to push the transfer chair up the 1:8 slope ramp and also to control the transfer chair while it is being brought down the ramp.

Advantages of the stair-lift:

- o The system uses external power and therefore requires less exertion on the part of the attendant.
- o The stair-lift is more compact than the ramp.

Disadvantages of the stair-lift:

- o Boarding with the stair-lift is a two person operation.
- o A manual override will have to be designed so that the system can be operated in a power failure.

Full-scale working models have been made on the chair and the two boarding systems. The tests which have been performed on the full-scale working models have shown the advantages of the new transfer chair and its acceptance by disabled volunteers.

Designs were made and models were constructed of a third bus-boarding system which could easily be stored in the luggage compartment of a bus and operated by the driver. Such a proposed system would be essential for safe transportation of physically disabled persons, as it could be used in the event of the bus breaking down away from bus terminals or other sources of assistance.

SOMMAIRE

Dans le but de rendre les transports publics accessibles aux personnes à mobilité réduite, Transports Canada a subventionné le développement de méthodes innovatrices leur permettant d'utiliser les autocars. Ce n'est pas un problème facile à résoudre.

Aux limitations physiques de l'handicapé, s'ajoute l'étroitesse des entrées et des allées que l'on retrouve dans ces autocars. Venir à bout des nombreuses difficultés d'un tel projet demande la capacité de conceptualiser le problème dans son ensemble, afin de développer des idées innovatrices.

Les principales innovations apportées proviennent de la considération des facteurs suivants:

- i) Pour monter dans l'autocar, la personne à mobilité réduite devra faire un ou deux transferts. Par exemple, si elle est venue en fauteuil roulant, elle devra transférer de son fauteuil au système d'embarquement et ensuite du système à un siège d'autocar. Ces personnes sont habituées à transférer d'un siège à un autre - préférentiellement de la même hauteur ou plus bas.
- ii) Un système utilisant un rail ou un support entre la première rangée de sièges et les escaliers, pourrait être encombrant lors du transfert à l'intérieur de l'autocar.
- iii) Un système idéal permettrait au premier transfert (du fauteuil roulant au système d'embarquement) d'avoir lieu à un endroit approprié à l'intérieur du terminus. L'appareil d'embarquement serait ensuite acheminé dans l'autocar juste à côté de la première rangée de sièges, où aucune autre restriction ne viendrait gêner le transfert. La mise au point de ce système idéal a commencé par le design et la fabrication d'un siège de transfert. Par la suite, deux différents systèmes ont été conçus en vue d'emmener le siège dans l'autocar et de l'acheminer à côté de la première rangée de sièges.

Le siège de transfert présente les caractéristiques suivantes:

- o La base du siège est montée sur des roulettes, lui permettant d'être bougée librement, aussi bien dans le terminus qu'à l'intérieur même de l'autocar. Ainsi, le transfert du fauteuil roulant au siège de transfert peut avoir lieu à l'endroit le plus approprié assurant le maximum d'intimité, de confort, de discrétion, de commodité, etc.
- o La hauteur du siège est ajustable, permettant des transferts de niveau (ou vers le bas) en tout temps. Le siège de transfert a six roulettes, dont deux ont une direction fixe, mais sont escamotables, et les quatre autres peuvent pivoter librement. Ceci donne un siège très maniable en tout temps, surtout dans les espaces restreints.
- o Dans le but d'obtenir un maximum de stabilité, le siège a été fait aussi large que possible en tenant compte des contraintes imposées par les dimensions de l'entrée de l'autocar et de la largeur de l'allée.

Deux différents systèmes ont été conçus afin d'acheminer le siège de transfert dans l'autocar. Le premier consiste en une rampe pliante qui se place le long de l'autocar. Le second système est une plate-forme motorisée déjà en usage pour monter un siège le long d'un escalier; il a été modifié pour transporter le siège de transfert jusqu'au niveau de l'allée de l'autocar. Les deux systèmes d'embarquement fonctionnent très bien, quoique chacun comporte des avantages et des désavantages.

Avantages de la rampe:

- o Le système ne dépend d'aucune source externe d'énergie, il fonctionne même pendant une panne d'électricité.
- o Ne requiert qu'une seule personne pour assister le voyageur pendant l'embarquement ou le débarquement, et cette personne est à proximité du voyageur en tout temps.

Désavantages de la rampe

- o Le système est passablement volumineux, même lorsque les sections sont remisées dans le compartiment principal.
- o L'assistant doit être en assez bonne condition physique pour pousser le siège de transfert en montant le long de la rampe, dont la pente est de 1:8, et aussi pour garder le siège sous contrôle en le descendant.

Avantages de la plate-forme motorisée:

- o Le système utilise une source d'énergie externe; il exige donc moins d'effort de la part de l'opérateur.
- o Le système est plus compact que la rampe.

Désavantages de la plate-forme motorisée:

- o Sa manipulation demande deux opérateurs.
- o Un système d'urgence manuel devra être ajouté de sorte que la plate-forme puisse être utilisée pendant une panne.

Des modèles d'étude du siège et des deux systèmes d'embarquement ont été fabriqués. Les essais ont démontré les avantages du nouveau siège de transfert ainsi que son acceptation par les volontaires à mobilité réduite.

Les designs et la construction d'un modèle réduit d'un troisième système d'embarquement ont été faits. Celui-ci aurait l'avantage d'être facilement transporté dans le compartiment à bagages de l'autocar et de pouvoir être utilisé même par le chauffeur en cas de besoin. Ce système tel que proposé serait essentiel à la bonne sécurité des personnes à mobilité réduite, car il pourrait être utilisé dans les cas d'urgence advenant un bris mécanique de l'autocar loin des terminus ou des services d'arrêts.

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1. INTRODUCTION

This project follows an earlier contract entitled "Novel Station-Based Boarding Device Concept for Inter-City Bus Applications" (contract serial No. T8080-6-2663/01/FT) which was performed by this author in 1984. Two of the three concepts presented in the earlier report were chosen for further development, including the construction of "mock-ups and full-scale working models".

The purpose of the present contract was to determine the feasibility of the two concepts, to identify their advantages and limitations, to make any necessary design changes, and to evaluate the systems' performance with the help of potential clients.

Because of the many difficulties which are inherent in the task of enabling physically disabled persons to board intercity buses, non-operational models (even full-scale models) would be inadequate for a complete evaluation of any proposed solution. Thus, full-scale working models had to be designed, constructed, and tested in realistic situations with physically disabled volunteers. Another benefit of using working models is that it will facilitate the ultimate transition to the manufacturing of production units.

Arising from the testing and evaluation of the models we have constructed, observations are made with respect to the development of operational prototypes and a proposal is made for the development of a portable system to enable disabled clients to be boarded and de-boarded away from a bus terminal.

2. STATEMENT OF THE PROBLEM

The major difficulties in enabling physically disabled persons to board inter-city buses are caused by: the small sizes of the entrances, the numbers of steps from the entrance to the aisle level, the heights of the steps, and the widths of the aisles. Steps in the aisles of some buses which occur before the first row of seats, present an additional problem.

It is impossible to bring ordinary wheelchairs into a conventional inter-city bus, primarily because they are too wide. Boarding systems which bring disabled persons into a bus using a boarding seat on a boom or other device, present problems when the disabled person is transferring to the boarding seat and also when he or she is transferring from the boarding seat to a bus seat. The first transfer would have to be done at the boarding mechanism, possibly in confined quarters and without any privacy. For the transfer to the bus seat, the boarding seat may not reach close enough and the boom may get in the way of persons assisting the transfer. Individuals who regularly use wheelchairs are accustomed to transferring from a wheelchair seat to a chair seat, and vice versa. These are straightforward transfers and can be accomplished quite smoothly. Transferring to or from a boarding seat which is reaching in through the bus entrance, will put the disabled person (and his or her helpers) in a very difficult and unfamiliar situation. This can lead to problems, both psychological and physical.

Other important factors associated with disabled persons boarding inter-city buses include:

- i) The number of operators required for bus-boarding.
- ii) The time taken by bus-boarding.
- iii) The complexity of the bus-boarding process.
- iv) The safety of the disabled person, the operators, and the other bus passengers.
- v) Any inconveniences to regular bus passengers.

3. PROPOSED SOLUTION UNDER INVESTIGATION

The proposed solution was originally outlined by this author in the final report on contract Serial No. T8080-6-2663/01/FT, in 1987. In that contract, the following boarding strategies were developed:

- 1) A special chair was to be designed and constructed, which would be small enough to fit through a bus entrance and to be brought beside the first row of seats. This chair should be as large as possible (within the above constraints); it should give a disabled occupant adequate support; its height should be adjustable; and it should be on wheels for easy maneuverability. The chair must be designed so that it does not itself add to the space constraints experienced by a seated person moving into a bus or down the aisle. Thus, for example, no side supports may protrude further than the user. The use of this special chair - called a transfer chair - is a key part of our proposed solution. The initial transfer from the disabled person's own wheelchair to the special chair can be performed at a convenient location - possibly inside the bus terminal itself. The transfer from the special chair to a bus seat will be relatively straightforward and will be constrained only by the available space inside the bus itself.
- ii) The next step in our proposed solution was to develop methods to get the special chair (the transfer chair) from the ground outside the bus to beside the first row of passenger seats. Three different methods were proposed in the original 1987 contract. Of these three methods, two of them were chosen for further development in this contract. One of the systems will use a ramp, and therefore require no external power. Furthermore, the operator pushing the special chair up the ramp will be in close proximity to the disabled person at all times. The second system will involve an adaptation of a commercial stair-lift, normally used to bring disabled persons up the stairs in their homes. This system will use external power, either the mains voltage at the terminal or the battery voltage in the bus itself. Taking into account the very severe space restrictions at the entrance to a bus, and taking into account the fact that some clients will be quite large, the two systems must be designed so that they do not themselves add to the space problems.

The proposed solution represents a significant improvement over existing bus boarding systems. It arose from discussions with clinical staff at the Rehabilitation Centre, and with disabled clients.

4. DESIGN OF THE TRANSFER CHAIR

A major component of the two bus-boarding systems is a specially designed transfer chair which can be used first to wheel the client through the bus terminal, and which can then be brought into the bus and beside the first row of passenger seats. Two drawings of the transfer chair are given in figures 1 and 2. It was designed and built to meet the following specifications:

- i) Maximum size - while satisfying the dimensional constraints of the bus entrance, the stairwell, and the aisle.
- ii) Adjustable seat height (46 cm to 59 cm) (18" to 23").
- iii) Removable push handle.
- iv) Adjustable grab bar height.
- v) Leg restraint bars.
- vi) Upper body restraint.
- vii) Auxiliary wheels (for straight tracking).

The transfer chair is compact enough so that it will fit through the door of a bus, the stairs, and the aisle. The size was maximized while satisfying the preceding restrictions, in order to provide adequate support for large clients and to provide maximum stability. Because of the narrow width of the bus aisle, there is an inherent limit on the size of a client that can be brought into position beside the first row of seats. The transfer chair was designed so that it does not itself impose a size limitation on clients which can board. Therefore the maximum size of the client that can be accommodated is governed only by the dimensions of the bus entrance and by the dimensions of the interior.

The height of the seat from the ground is adjustable from 46 cm (18") to 59 cm (23") by activating a foot pedal attached to an hydraulic pump. The lifting mechanism is a modified version of the hydraulic lift that is used in a barber chair. This height adjustment is necessary to ensure that level (or high-to-low) transfers are available in all situations.

A push handle at a height of 90 cm (35.4") is provided at the front of the transfer chair for maneuvering purposes. Built into the push handle assembly are the grab bar and the leg restraints. The grab bar is used by the client as a transfer aid and as an aid in maintaining upper body balance when seated in the transfer chair. Safety and a sense of security are improved, from the client's perspective, because there is something to hold on to. The grab bar is adjustable in height. However, it is normally set at 81 cm (32") from the ground and no adjustment has been necessary so far. The leg restraints are composed of padded bars which flip down from the push handle assembly to the front of the seat on each side. These leg restraints keep the clients' knees from falling open. They are necessary to prevent accidental impact between the client and the bus or the lift systems, during the boarding process. The whole push handle assembly, including the grab bar and the leg restraints, can easily be removed by

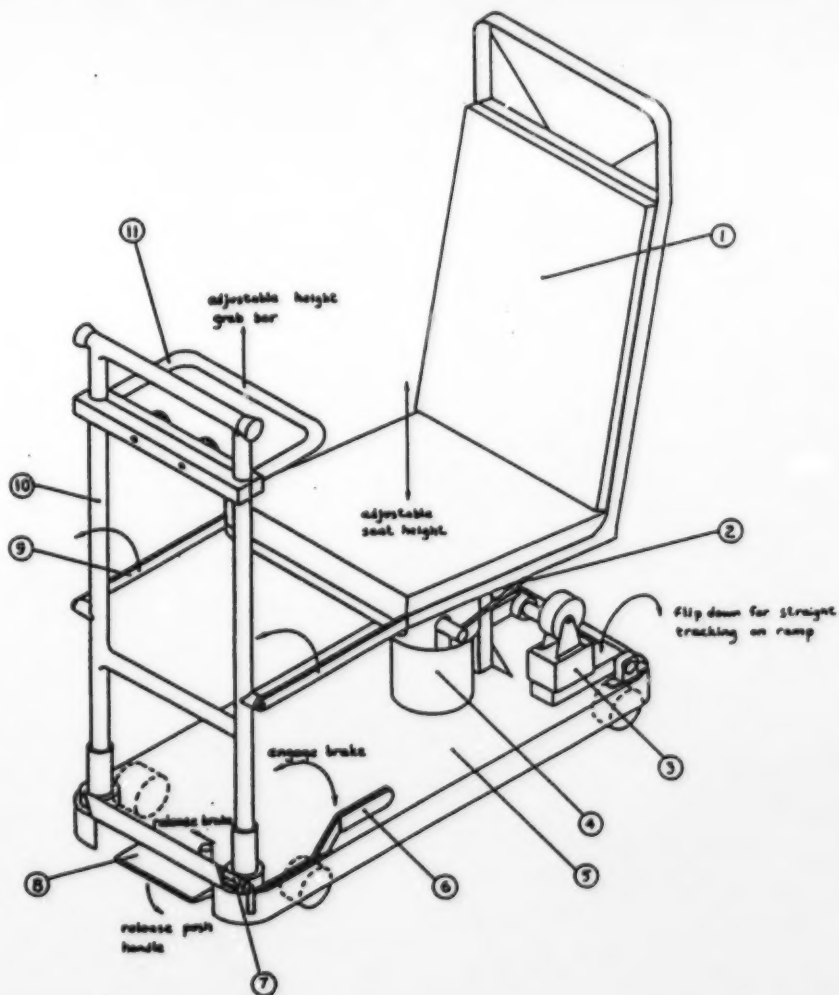
means of a foot pedal release at the front of the chair. For certain clients, and especially for those requiring assisted transfers, a transfer may be most efficiently performed with the push handle assembly removed.

The parking brake used on the transfer chair operates on a similar principle to that of floor locks. The four casters of the chair are completely lifted off the ground when the brake is engaged. This parking brake is used during transfers, during ascent/descent on the stair-lift system, and in any emergencies such as operator fatigue while pushing the transfer chair up the ramp.

A four point restraint system, in the form of two independent shoulder belts, is used to secure the client in the chair. Physical barriers beside the client, such as panels along the shoulder and hip areas, are not used because they would decrease the maximum size of persons that could use the boarding system.

A set of auxiliary wheels can be flipped down from the back of the transfer chair base and locked into place to facilitate steering. This is needed, for example, when using the ramp system. The extra set of wheels improve the straight-line tracking of the chair, and this is important when travelling up the ramp or when wheeling a client through a busy terminal. Since the transfer chair has to have maximum maneuverability in the confined bus interior, the auxiliary wheels can be raised and tucked neatly out of the way when not needed.

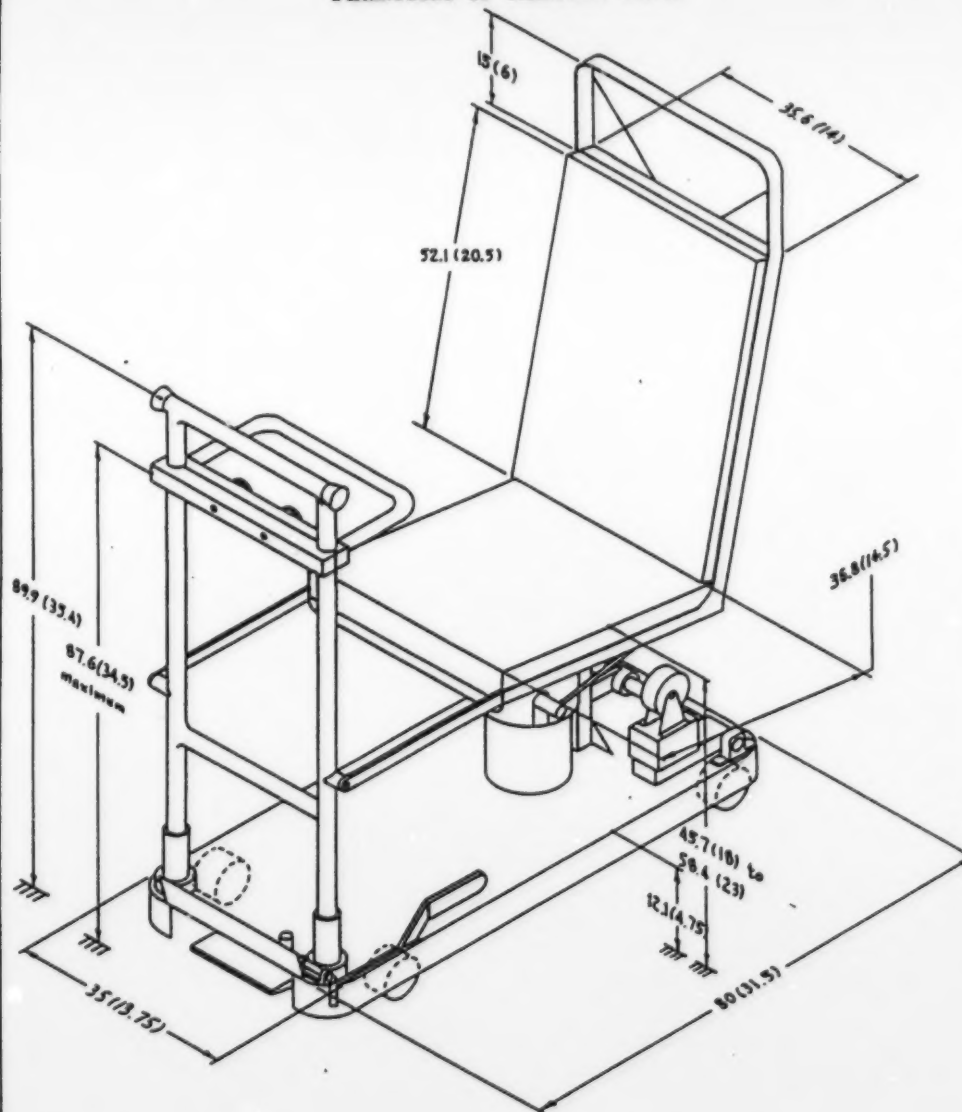
FIGURE 1
DRAWING OF TRANSFER CHAIR



11	GRAB BAR
10	PUSH HANDLE ASSEMBLY
9	LEG RESTRAIN
8	PUSH HANDLE RELEASE PEDAL
7	PARKING BRAKE LOCK/RELEASE PIN
6	PARKING BRAKE LEVER
5	BASE
4	HYDRAULIC CYLINDER
3	AUXILIARY WHEEL ASSEMBLY
2	SEAT HEIGHT ADJUSTMENT PEDAL
1	SEAT
ITEM No.	DESCRIPTION

THE REHABILITATION CENTRE
TRANSFER CHAIR
DR BY: RC DATE: 89.03.20
SCALE: 1:6
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FIGURE 2
DIMENSIONS OF TRANSFER CHAIR



ALL DIMENSIONS IN CENTIMETRES WITH INCHES IN BRACKETS.

/// denotes ground level.

THE REHABILITATION CENTRE	
TRANSFER CHAIR	
DR BY: RC	DATE: 89.03.20
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5. DESIGN OF RAMP BOARDING SYSTEM

In designing a ramp system for use in bringing the transfer chair from ground level to the aisle of the bus, a number of factors had to be taken into account. These are:

- i) The slope of the ramp, which was a major determinant in the force needed to push both transfer chair and occupant up to the level of the bus aisle.
- ii) Difficulties in bringing the transfer chair safely down the ramp, without the danger of the attendant stumbling or letting go.
- iii) The risk of the chair (occupied or not) rolling down the ramp and causing injury to the occupant or to passers by.
- iv) The bulkiness of the complete ramp system.
- v) The ability of the ramp to fold up, for moving or storage.
- vi) Difficulties in moving the folded ramp throughout the bus terminal.

A prototype ramp was designed and constructed primarily of plywood and Dexion steel angles. Dexion was chosen to facilitate modifications and adjustments being made during design and construction. Schematic drawings of the ramp are shown in figures 3 and 4. The ramp is shown in operation in figure 5. The total length of the extended ramp is 1016 centimetres and the minimum width is 76 centimetres. It is constructed in four sections, with sections 2, 3, and 4, folding into section No. 1. Thus, the folded ramp is 284 centimetres long, by 113 centimetres wide, by 205 centimetres high. When the ramp is fully opened, the maximum slope is 1 in 8.5 (6.6'). This slope is greater than the 1 in 12 slope recommended for permanent structures in buildings. However, it is less than the 1 in 4 slope which is the maximum gradient allowed by CSA standard CAN3-D409-M84. The original ramp which we constructed had just three sections and a steeper slope. However, preliminary tests showed that too much effort was required to bring a client and the transfer chair up the ramp. Thus a fourth section was added, giving a maximum slope of 1 in 8.5. Appropriate guard rails and floor-level lips were put on the ramp to prevent the client or the attendant from falling off. The guard rail is also useful to steady the attendant while the chair is being lowered down the ramp.

The top of the ramp contains a level platform with a width of 113 centimetres and a minimum length of 122 centimetres. This level platform is used to turn the transfer chair around and bring it up the extra ramp which goes right into the bus. Sufficient head clearance is available even for a tall client. However, the attendant will have to duck his or her head slightly. So that the transfer chair can be brought into the bus and maneuvered to the first row of seats, the pair of non-swivelable wheels will have to be raised at this time enabling the chair to be moved on its four primary castors. The chair is then moved beside the first row of seats. The armrests of the first row of seats will have to pivot upwards so that a level transfer can be made. Any height discrepancy between the transfer chair and the seat can be corrected before the transfer is

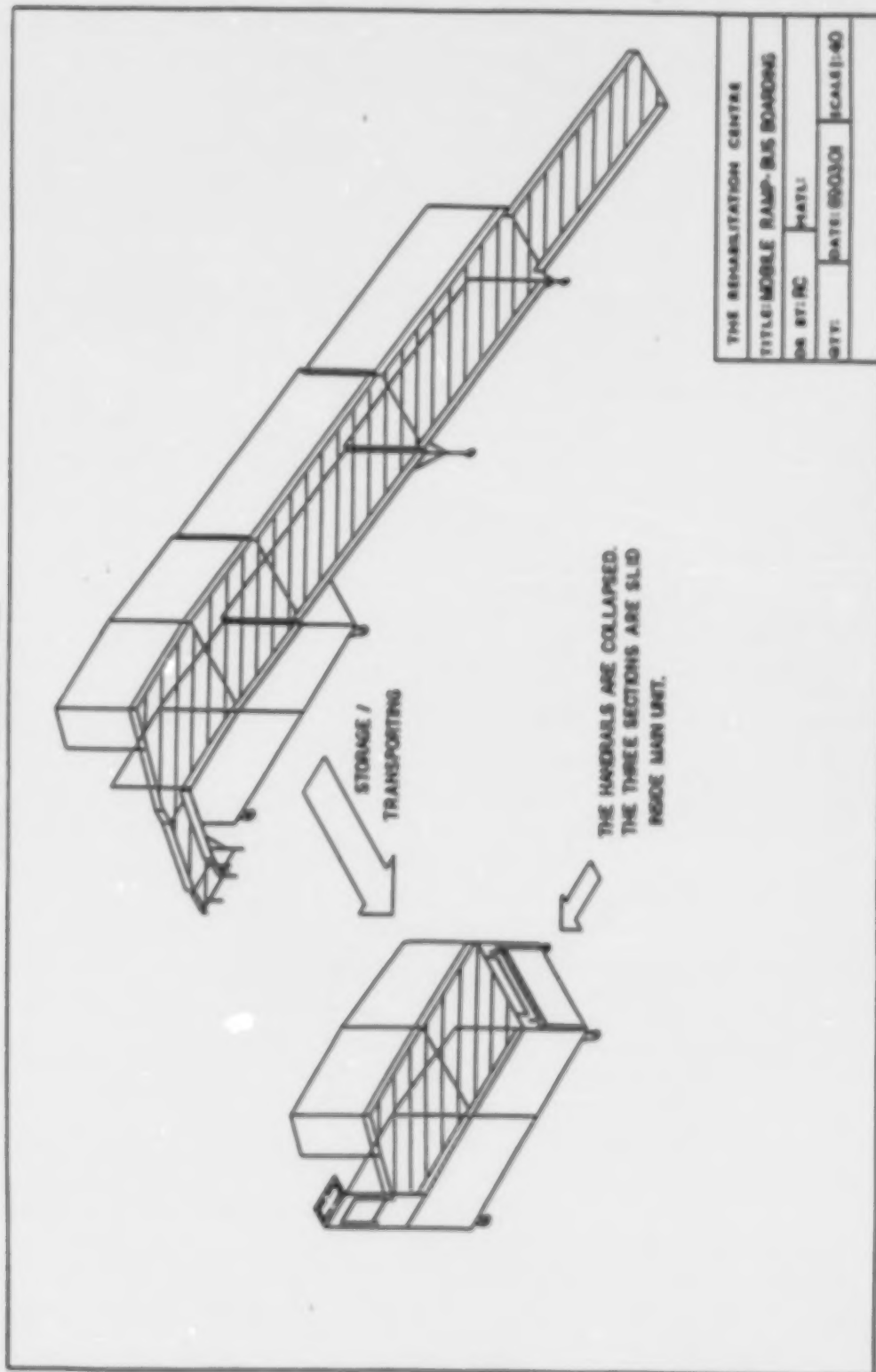
made, by adjusting the height of the seat on the transfer chair. However, the transfer chair must be at its lowest position while going up the ramp and into the bus. Raising the seat prior to going into the bus could result in the client hitting his or her head against the top of the bus doorway.

While the ramp was being designed, computerized stress analysis was performed to ensure that none of the structural members would be over-stressed while the ramp was being used. Appropriate design changes were made to the structure of the ramp at this stage, in order to keep all stresses below safe limits. A sample printout of the stress analysis is shown in figure 6.

As a further aid to the attendant pushing the wheelchair up the ramp, the surface was coated with abrasive paint. If at any time, the attendant felt that he or she needed to take a rest, the brakes on the transfer chair could be applied. These brakes are effective enough to hold the transfer chair on the ramp without any slippage.

This boarding process can be performed by a single attendant, who is in close proximity to the client at all times from ground level to the bus seat.

FIGURE 3 DRAWING OF RAMP



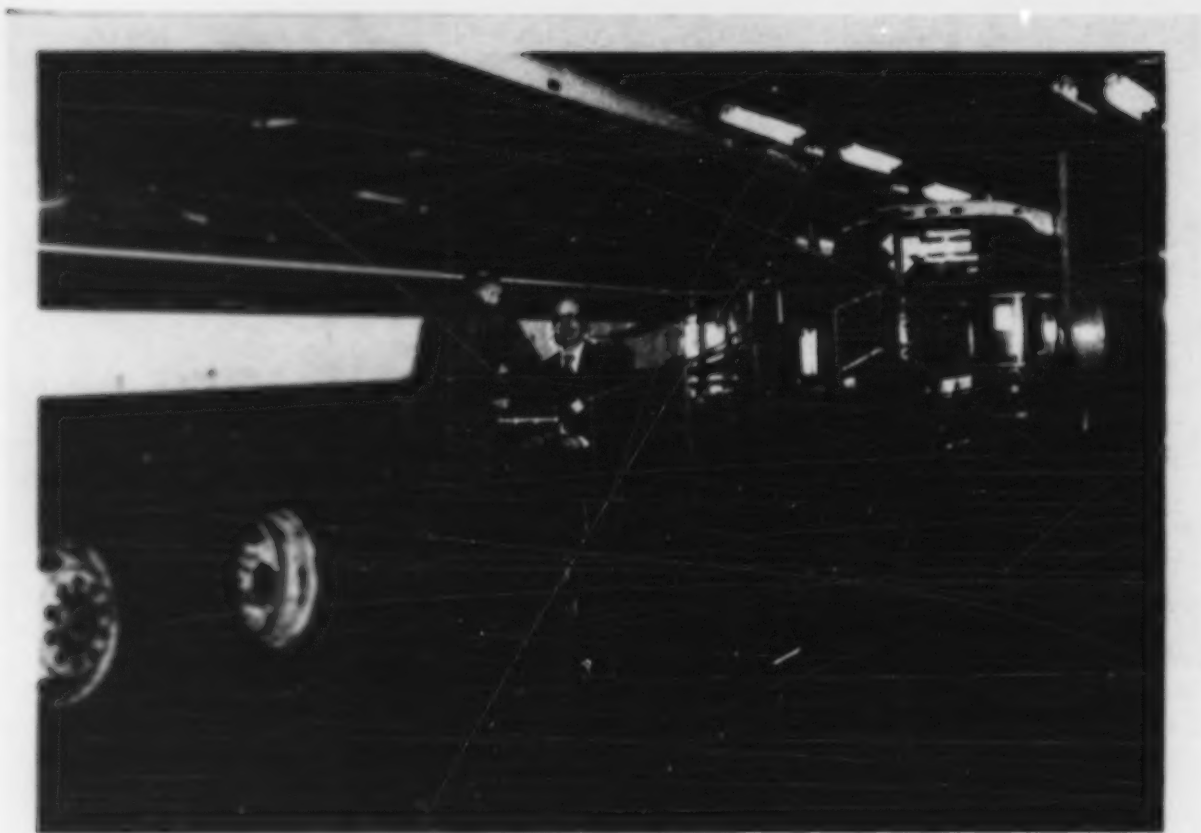
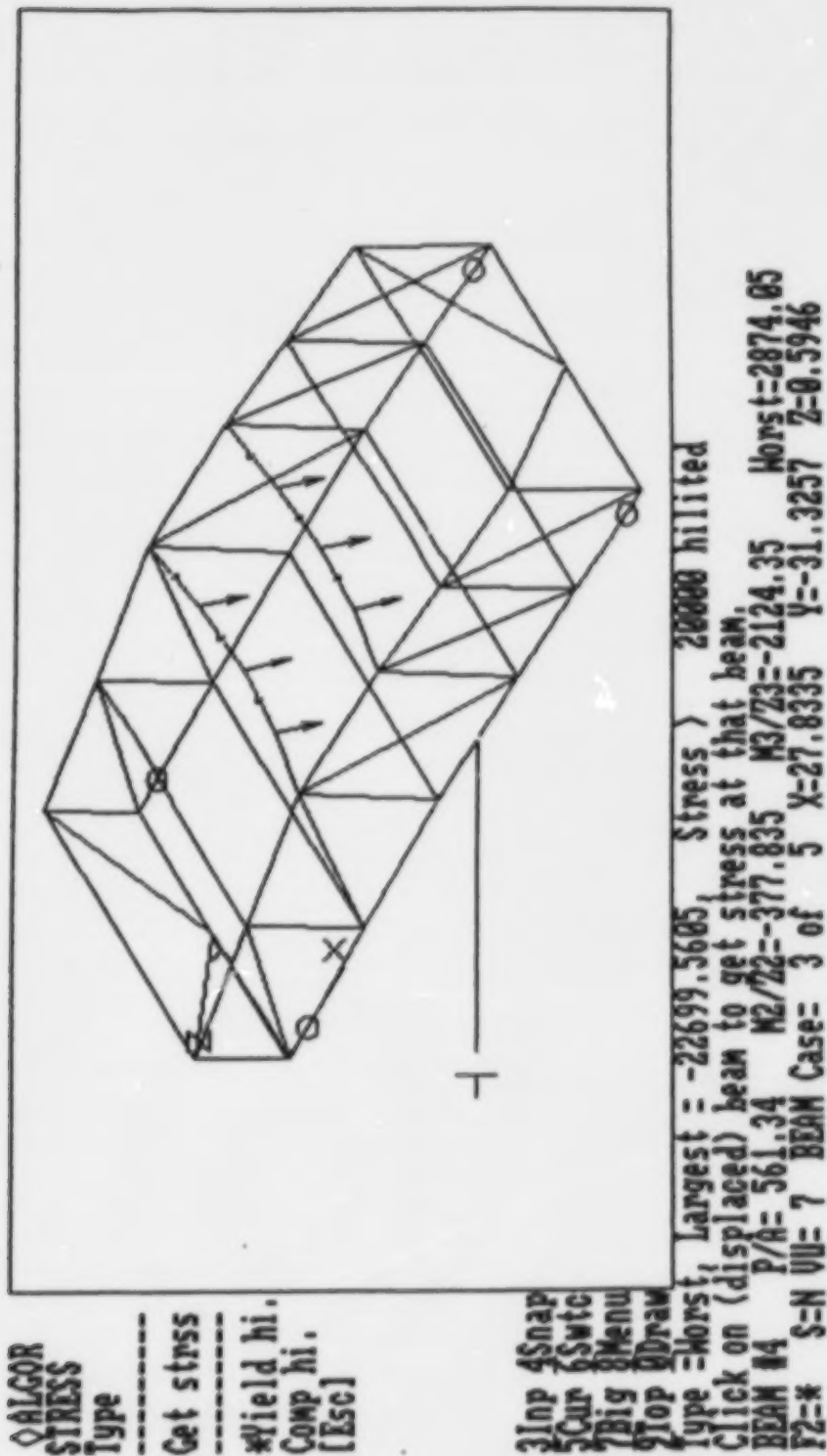


FIGURE 5

RAMP IN USE TO BRING TRANSFER CHAIR INTO BUS

FIGURE 6 STRESS ANALYSIS OF RAMP DESIGN



6. DESIGN OF STAIR-LIFT SYSTEM

This system uses electric power to bring the transfer chair from ground level into the bus. The chair is then wheeled beside the first row of passenger seats. For our prototype, we adapted a conventional stair-lift mechanism which is designed to bring disabled persons up the stairs in their own homes. There were several advantages in starting with an existing commercial system:

- i) An appropriate mains-operated motor was provided.
- ii) Safety systems provided with the stair-lift prevent the motor from going too far (up or down) and hold the system securely in place in the event of cable breakage or a slack cable.
- iii) The on/off and up/down controls of the original stair-lift system could be used.

A new rail was designed and constructed from aluminum. A schematic drawing of the system is shown in figure 7. The whole assembly can be wheeled to a bus entrance. An interface platform, as shown in figure 10, is placed on the top two steps of the entrance to the bus. This is used to make the connection between the stair-lift system and the bus. It also provides additional level space to turn the transfer chair prior to wheeling it down the aisle.

The stair-lift system is comprised of three distinct components: the main unit, the interface platform, and the service ramp. The main unit contains the track, the motor, the controls, and a platform on which the transfer chair is placed. The interface platform provides an attachment point for the track, and bridges the gap between the transfer chair platform and the landing at the top of the stairway. The service ramp is used to raise the transfer chair from ground level to the lowest position of the transfer chair platform. The service ramp is shown being used in figure 8. The stair-lift is shown bringing a person into a bus in figure 9. For the purpose of transporting the stair-lift, both the interface platform and the service ramp can be stored on the main unit. The complete system can then be wheeled to the bus entrance, prior to being set up for operation.

There are several reasons why the interface platform is necessary and why it cannot be integrated into the main unit. An early design visualized the transfer chair being pushed directly onto or off of the landing at the top of the stairwell, with the motor located beside the track. There were problems with the convoluted cable path between the motor and the transfer chair platform. In addition there were difficulties in keeping the overall width of the device to less than 90 cm, which is necessary for maneuverability through doorways in the terminal. It was decided that locating the motor underneath the track would solve the above two problems. To prevent interference between the motor and the bottom step of the coach, and to accommodate the maximum door angle of 70°, it was necessary to move the whole system in the direction of the coach entrance. This made the interface platform necessary. The interface platform must occupy the full width of the bus stairwell for safety, maximum maneuverability of the transfer chair, and simplicity of positioning. A flip-up portion was designed into the platform to facilitate positioning and to avoid damage to the bus

stairwell. For the same reasons, the interface platform remained separate from the track instead of permanently attached to it.

The service ramp is used to overcome the 31 cm (12") difference in height between the lowest level of the transfer chair platform and the ground. The service ramp has a slope of 1:5. A gradient of 1:4, which is the maximum gradient allowed by CSA standard CAN3-D409-M84, was initially tried. Pushing the transfer chair up the 1:4 slope required too much effort and the 1:5 slope was therefore chosen. The transfer chair platform cannot be lowered to ground level because it has to be structurally supported from the underside. The 31 cm height from the ground is required to support the platform safely and to provide adequate ground clearance during transport. The alternative of supporting the platform from above was rejected because the supporting structure would protrude into the stairwell and interfere with the maneuvering of the transfer chair in the confined area at the front of the aisle.

The stair-lift can accommodate a variation in the height of the landing (at the top of the stairwell) of between 105 cm (41.25") and 129 cm (50.75") from the ground. This is necessary to allow for differences between buses, different tire pressures and different amounts of air in the suspension system.

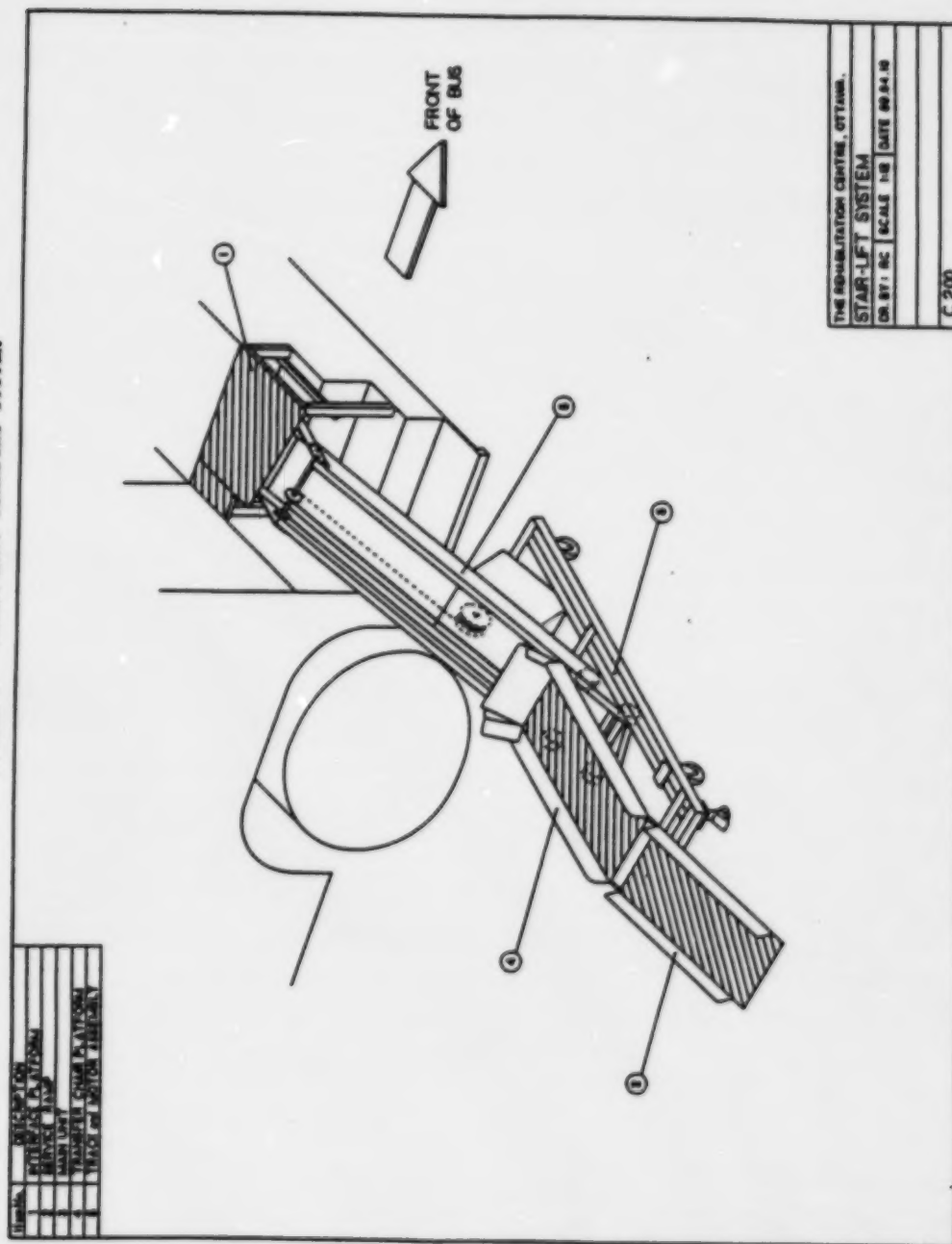
The use of the stair-lift system to board a disabled person requires two attendants. The main reason for this is that once a platform containing the transfer chair is brought to the top of the stair-lift, entrance to the bus by the attendant is effectively blocked. Thus a second attendant must already be in the bus, so that he or she can wheel the chair off the platform and bring it to the first row of passenger seats. The complete boarding procedure is as follows:

- i) The stair-lift system is wheeled to the bus and attached securely.
- ii) Attendant number "1" enters the bus - if necessary using the elevating platform.
- iii) Attendant number "2" wheels the transfer chair up the service ramp and onto the platform. The brakes are then applied and the chair is secured.
- iv) Attendant number "2" operates the stair-lift, which brings the disabled client up the bus stairs.
- v) Attendant number "2" unlocks the transfer chair and attendant number "1" brings it beside the first row of passenger seats. Attendant number "1" then helps the client transfer to a bus seat.

De-boarding is performed by reversing the above procedures.

The stair-lift system weighs 157 kg. Thus even if it could be disassembled into two or three components, they would be too heavy (and also too bulky) to store in the luggage compartment of the bus.

FIGURE 7 STAIR-LIFT BOARDING SYSTEM



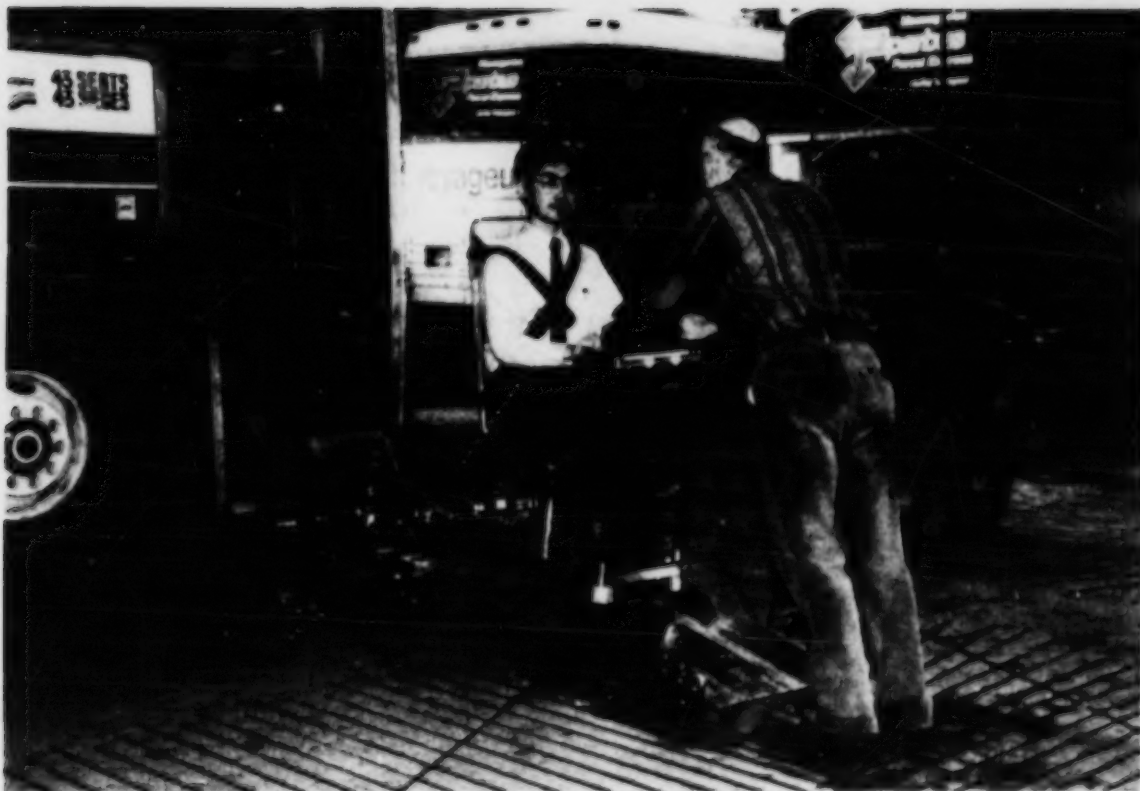


FIGURE 8

SERVICE RAMP IN USE TO BRING TRANSFER CHAIR FROM GROUND LEVEL TO PLATFORM

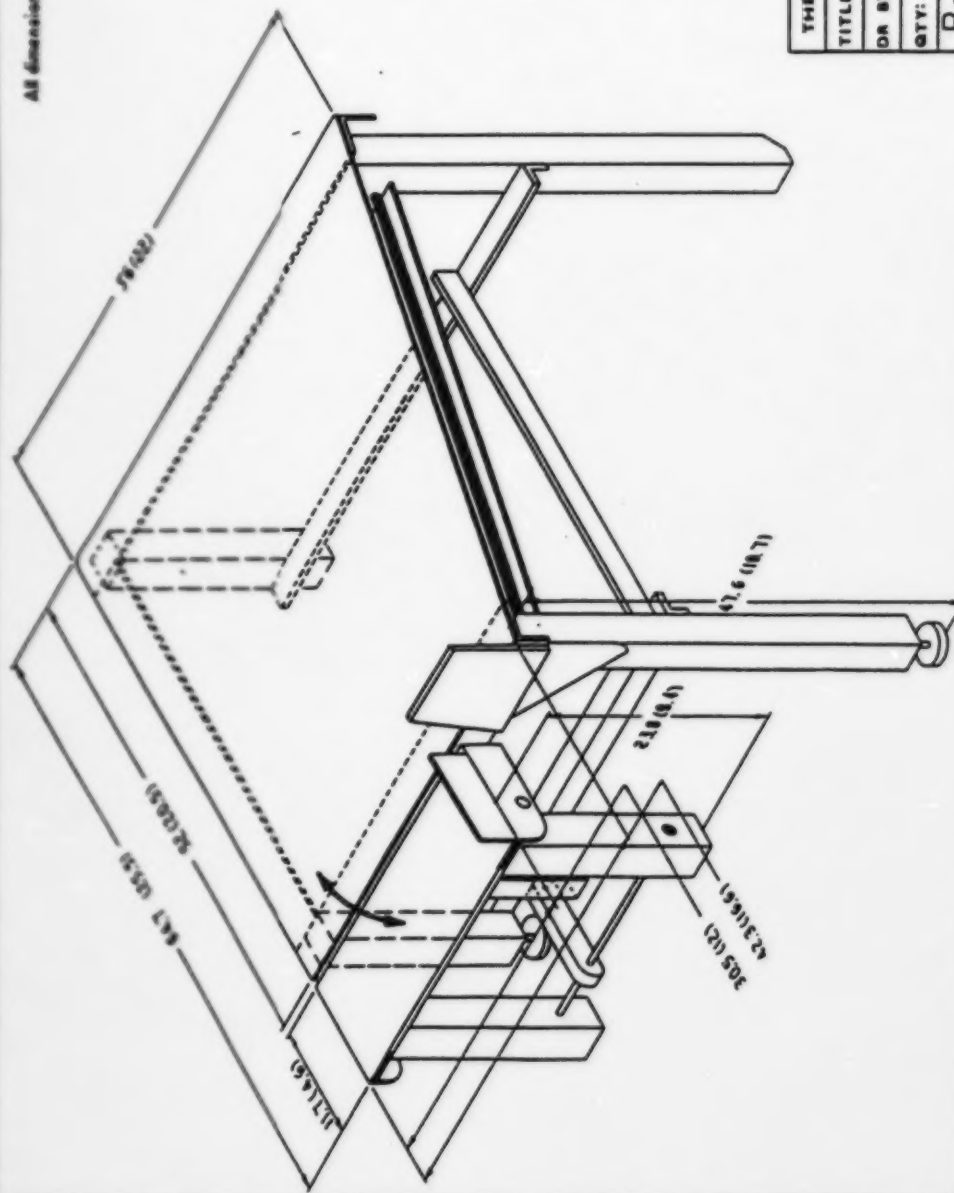


FIGURE 9

STAIR-LIFT SYSTEM BRINGING TRANSFER CHAIR INTO THE BUS

FIGURE 10 BUS-LIFT INTERFACE PLATFORM

All dimensions in centimetres with inches in brackets.



THE REHABILITATION CENTRE			
TITLE: BUS-LIFT INTERFACE PLATFORM ASSEMBLY			
DR BY: RC		MAYL:	
QTY:	DATE: 89 03 13	SCALE 1:4	
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7. TESTING AND EVALUATION OF THE TWO BUS BOARDING SYSTEMS

When performing tests on the two station-based bus boarding systems, it was necessary to keep in mind the original purpose of the contract. The contract was not awarded for the construction of operational prototypes which could be tested at various bus terminals. Rather, the contract specified the construction of "mock-ups and full-scale working models". The difference here is that operational prototypes must satisfy a much more comprehensive list of design criteria, including exterior appearance, seat padding, etc. However, it is sufficient for "mock-ups and full-scale working models" to demonstrate the feasibility of the systems and to establish beyond doubt that operational prototypes could be constructed.

7.1 Use of Pre-Designed Evaluation Sheet.

This section makes use of a "SAMPLE STATION BASED LIFT DEVICE EVALUATION SHEET", which is given in the report entitled "Station-Based Lift for Intercity Buses Design Criteria", which was performed for Transport Canada in 1987. The number of this report is: TP 8803E. A copy of the sample evaluation sheet is reproduced in the following 5 pages. Some of the criteria will be marked N/A, as they do not apply to our mock-up systems at their present state of development.

SAMPLE STATION BASED LIFT DEVICE EVALUATION SHEET

SUGGESTED DESIGN CRITERIA			ALTERNATIVES	
	IDEAL	MINIMUM ACCEPTABLE	"A"	"B"
(1) Exterior Appearance			<u>Score</u>	<u>Score</u>
(a) Obtrusiveness	• Blends into architecture and vehicle environment.		_ x (30) = ____	_ x (30) = ____
(b) Form	• Integration of colours, surface textures and structural components.		_ x (30) = ____	_ x (30) = ____
(c) Protrusions	• No sharp corners or overhanging structures.	• Corners or overhanging structures are mitigated.	_ x (40) = ____	_ x (40) = ____
			<u>Σ (10)</u>	<u>Σ (10)</u>
			_____	_____
(2) Device/Coach Interface			<u>Score</u>	<u>Score</u>
(a) Compatibility to various coach designs	• Current intercity bus fleet.	• MCI-"MC3", Prevost - "Marathon/Mirage".	_ x (20) = ____	_ x (20) = ____
(b) Requirements for bus modifications	• None.	• Minor coach modifications limited to coach entrance/stairwell area components.	_ x (20) = ____	_ x (20) = ____
(c) Level of effort required to deploy the device	• 2 minutes - minimal effort with clear visible reference points for positioning device in the stairwell.	• 3 minutes - medium effort with reference points provided to position device.	_ x (20) = ____	_ x (20) = ____
(d) Physical link	• Positive link between coach and proposed device.	• High friction connection.	_ x (10) = ____	_ x (10) = ____
(e) Visual cues for positioning device	• Provide high target value under all lighting and weather conditions.	• Provide clear target under most lighting and weather conditions.	_ x (10) = ____	_ x (10) = ____
(f) Damage risk to coach during interfacing process	• Provide complete protection to coach doorway and stairwell components during use.	• Minimal risk for limited damage to coach doorway and stairwell components during use.	_ x (10) = ____	_ x (10) = ____
			<u>Σ (10)</u>	<u>Σ (10)</u>
			_____	_____

SAMPLE STATION BASED LIFT DEVICE EVALUATION SHEET (Continued)

	SUGGESTED DESIGN CRITERIA		ALTERNATIVES	
	IDEAL	MINIMUM ACCEPTABLE	"A"	"B"
(B) Passenger Safety/Comfort			<u>Score</u>	<u>Score</u>
(a) Passenger protection	- No exposure (of limbs and/or clothing) to moving or rotating parts. Complete body support to avoid contact with coach during ascent/descent. - Provide comfort/safety belt to insure passenger is properly positioned in seat.		__ x (20) = ____	__ x (20) = ____
(b) Passenger comfort	All components of the device which physically come in contact with the passenger should be covered or padded and be warm to touch.	Major components which come in contact with the passenger should be padded.	__ x (10) = ____	__ x (10) = ____
(c) Level of effort required for transfer	Minimal (unassisted).	Medium - 1 person assisting.	__ x (12) = ____	__ x (12) = ____
(d) Seat comfort	- Padded with medium density foam to avoid "bottoming". - Armrest padding to be firm. - Measure 90 cm across/40 cm deep with a seat backrest angle of 103-110°, a seat angle of 3-10° and an armrest height of 18-20 cm above seat height.	Padded seat, measure 40 cm across and deep and provide stable armrest.	__ x (10) = ____	__ x (10) = ____
(e) Armrests	- Armrests should extend beyond the front of the chair to aid those transferring passengers with upper body strength. - Armrests should be stable and individually support 43 kg.		__ x (10) = ____	__ x (10) = ____
(f) Footrest	- Lower limbs should be supported under the soles, on back of heels and laterally, noting a high proportion of potential users have little control over their lower limbs. - Footrest should support 112 kg passenger and be located as close to the ground as possible during the transfer into the chair.	Footrest should support 100 kg passenger.	__ x (2) = ____	__ x (2) = ____
(g) Ascending and descending acceleration	Gradual acceleration (not to exceed 90 cm/sec²).		__ x (10) = ____	__ x (10) = ____
(h) Vibration of passenger seat	No significant vibration.	Minimal vibration.	__ x (10) = ____	__ x (10) = ____
(i) Noise levels during operation	Comparable to light traffic at 1.5 m, may be considered intrusive (60dB).	Comparable to highway traffic at 1.5 m, telephone difficult to use (70dB).	__ x (10) = ____	__ x (10) = ____
			<u>8 (20)</u>	<u>8 (20)</u>

SAMPLE STATION BASED LIFT DEVICE EVALUATION SHEET (Continued)

	SUGGESTED DESIGN CRITERIA		ALTERNATIVES	
	IDEAL	MINIMUM ACCEPTABLE	"A"	"B"
(4) Functional Adequacy			<u>None</u>	<u>None</u>
(a) Personnel Requirements to maneuver, position and assist the passenger, transfer and seat the passenger.	Maximum one person.	Maximum 2 persons.	__ x (10) + __	__ x (10) + __
(b) Preboarding	Not required.	Preboarding required but in a designated area.	__ x (10) + __	__ x (10) + __
(c) Ease with which it can be moved about the terminal (operating environment)	Accommodate 5-2% sloping platform and 5-30 cm curb height and varying concrete/asphalt surface.	Accommodate varying 5-1% sloping platforms and 5-15 cm curb height and concrete surfaces.	__ x (10) + __	__ x (10) + __
(d) Effort/time required to transport device from storage to the platform area	A sustained push/pulling/lifting force of less than 130 N for no longer than 2 minutes duration (transport time less than 3 minutes).	A sustained push/pulling/lifting force of less than 130 N for no longer than 4 minutes duration (transport time less than 8 minutes).	__ x (10) + __	__ x (10) + __
(e) Aids for transporting device	Adjustable height from 85 to 100 cm providing good grip and friction qualities able to accommodate 95th percentile male hand with gloves.	Fixed height between 85-100 cm with good grip and able to accommodate 95th percentile male hand with gloves.	__ x (10) + __	__ x (10) + __
(f) Centre of gravity	Shall be located to minimize the propensity to overturn while sufficiently high to minimize effort required to move the device when force is applied to the handles.	No overturning potential under normal operation.	__ x (10) + __	__ x (10) + __
(g) Width (while transporting)	Maximum 90 cm	Maximum 100 cm	__ x (10) + __	__ x (10) + __
(h) Device positioning	Positive immobilizing position required for device on platform surface and on coach floor landing, adjustable according to coach type. If foot controlled, foot remains on floor and applies a maximum force of 3 N. When hand controlled, lever may travel through a maximum of 150° angle with a maximum force of 30 N.		__ x (10) + __	__ x (10) + __
(i) Portability	Stored in the bus baggage area.	Limited to remaining at the terminal.	__ x (10) + __	__ x (10) + __
			<u>2.10</u>	<u>2.10</u>

SAMPLE STATION BASED LIFT DEVICE EVALUATION SHEET (Continued)

		SUGGESTED DESIGN CRITERIA		ALTERNATIVES	
		IDEAL	MINIMUM ACCEPTABLE	"a"	"b"
(3) Accessibility				<u>Score</u>	<u>Score</u>
(a) Seat design	• Seat height adjustable 15-30 cm.	• Seat height (47 cm).	• Feetrest to seat separation (47 cm).	• $\leq (1.5) \times$ _____	• $\leq (1.5) \times$ _____
	• Feetrest to seat separation adjustable 15-30 cm.	• Stable chair, feetrest and supporting removable armrest.	• Stable chair, feetrest and supporting removable armrest.		
	• Minimal physical contact between passenger and operator while adjustments are carried out.				
	• 80 $\pm$ 1.00 cm is required adjustment to the lift device on the platform to ensure passengers may adequately perform the transfer into the seat.			• $\leq (1.5) \times$ _____	• $\leq (1.5) \times$ _____
(b) Device size/area remaining for passengers	• Less than 2 to 3 minutes.	• Less than 3 minutes.		• $\leq (1.5) \times$ _____	• $\leq (1.5) \times$ _____
(c) Transfer time from when the passenger begins to transfer into device chair until the passenger is seated into the coach				<u>2.10</u>	<u>2.10</u>
				_____	_____
(4) Technical Requirements				<u>Score</u>	<u>Score</u>
(a) Power	• Either self contained source or obtained from coach.	• Self contained, obtained from coach or 110 AC from terminal building.		• $\leq (1.5) \times$ _____	• $\leq (1.5) \times$ _____
(b) Manual override	• Device should be equipped with an easily accessible manual override system requiring maximum effort by the operator. (Five minute activation time.)	• Device should be equipped with an easily accessible manual override system requiring maximum effort by the operator. (Five minute activation time.)		• $\leq (1.5) \times$ _____	• $\leq (1.5) \times$ _____
(c) Lift/chair speed	• Infinitely variable from 0 to 7.5 metres per minute.	• Variable, 1.2 metres per minute increments, maximum 7.5 metres per minute.			
(d) Selection of components	• Exclusive use of standard off the shelf components/hardware.	• Minimum use of standard off the shelf components/hardware.		• $\leq (1.5) \times$ _____	• $\leq (1.5) \times$ _____
(e) Pay load	• 117 kg	• 100 kg		• $\leq (1.5) \times$ _____	• $\leq (1.5) \times$ _____
(f) Design load	• 273 kg, i.e., safety factor of 5.	• 400 kg, i.e., safety factor of 4.		• $\leq (1.5) \times$ _____	• $\leq (1.5) \times$ _____
(g) Design life	• 1200 cycles minimum (3 years in service)	• 1000 cycles minimum (3 years in service)		• $\leq (1.5) \times$ _____	• $\leq (1.5) \times$ _____
(h) Maintenance/Serviceing	• Not required throughout design life.	• Service required twice a year.		• $\leq (1.5) \times$ _____	• $\leq (1.5) \times$ _____
		• Good access to all serviceable components.		<u>2.7</u>	<u>2.7</u>
				_____	_____

SAMPLE STATION BASED LIFT DEVICE EVALUATION SHEET (Continued)

		SUGGESTED DESIGN CRITERIA		ALTERNATIVES	
		IDEAL	MINIMUM ACCEPTABLE	"A"	"B"
(P)	Control System			<u>Score</u>	<u>Score</u>
				<u>x (10) =</u>	<u>x (10) =</u>
(a)	Control system features	- Fail-safe device - in the event of power failure, average power spent less than 7.8 mW/mph/minute. - Equipped with a device to prohibit operation when not properly controlled and/or engaged. - Automatic reset control to reset all controls to the off position (when power is interrupted). - Automatic deceleration near the termination of up and down chair motion.			
(b)	Position of control panel	- Placement of the seat/chair up/down with speed adjustment. - Stopping of seat/chair gradually. - Indicate operation status "on" or "off". - All controls to provide audio feedback (i.e., clicks).	Adjustable speed on the control panel.	<u>x (10) =</u>	<u>x (10) =</u>
(c)	Location of controls	- If remote controlled it should be shock resistant material and contain no damage or switch activation from a 1.5 m fall onto concrete surface. - Remote control unit should fit in one hand and be activated with same hand (either right or left) with or without gloves. - Fixed control panel should be located to ensure operator has unobstructed view of the entire operation and be mounted 100-110 cm or an angle of 0-15°.		<u>x (10) =</u>	<u>x (10) =</u>
(d)	Informational provided on controls	- Both official languages, using symbols and colours to clarify and highlight functions, with up controls on the upper part of the panel and down on the lower part. - Provide illumination at night.		<u>x (20) =</u>	<u>x (20) =</u>
(e)	Switch type	- Push buttons - 2.5 sq.cm area with maximum 32 mm fully depressed using a force of 1 to 8 N. - Barrier (lip) to prevent accidental activation of push buttons.		<u>x (10) =</u>	<u>x (10) =</u>
				<u>x (10)</u>	<u>x (10)</u>
				<u> </u>	<u> </u>
TOTAL ALL DESIGN CRITERIA (SUM OF SUB-TOTALS) <u> </u>					

STATION BASED LIFT DEVICE EVALUATION SHEET

(1) Exterior Appearance

- (a) Obtrusiveness N/A
- (b) Form N/A
- (c) Protrusions N/A

(2) Device/Coach Interface

- (a) Compatibility to various coach designs
The two boarding systems can be adapted to any bus having an aisle "well" of 14" wide or more. Special interface platforms may be required for buses which have a step along the aisle before the first row of passenger seats.
- (b) Requirement for bus modifications
The only bus modification required is to make the armrest of the front passenger seats flip up. This modification is necessary to perform level transfers from the transfer chair to the bus seat. It should be noted that the new MC-10 bus comes with flip-up arm rests on all seats.
- (c) Level of effort required to deploy the device
Both boarding systems can be set up in a few minutes. However more than three minutes are required for our full-scale mockups. An operational prototype would work much more smoothly and would probably take no more than three minutes and require only medium effort.
- (d) Physical link
The physical links are fully adequate.
- (e) Visual cues for positioning device
These are adequate.
- (f) Damage risk to coach during interfacing process
Risk of damage is minimal.

(3) Passenger Safety/Comfort

- (a) Passenger protection
There is no exposure of limbs and/or clothing to moving or rotating parts. Complete body support is provided to avoid contact with coach during ascent/descent.

- | | |
|--|---|
| (b) Passenger comfort | Good. |
| (c) Level of effort required to transfer | The seat of the transfer chair is level and adjustable in height. The grab bar can be removed for transfer. Thus, the transfer will be as easy as is possible within the confined space of the bus aisle. |
| (d) Seat comfort | Padded. |
| (e) Armrests | There are no armrests on the transfer chair as they would markedly reduce the maximum size of a client which could be accommodated. Grab bars are provided for clients who have the use of their arms. Two independent and adjustable belts prevent the clients from falling forward or sideways. |
| (f) Footrest | Appropriate foot and leg restraints are provided. |
| (g) Ascending and descending acceleration | For the stair-lift system, the ascending and descending acceleration is appropriate for disabled clients. |
| (h) Vibration of passenger seat | Not a problem. |
| (i) Noise level during operation | Not a problem |
| (4) Functional Adequacy | |
| (a) Personnel requirements to manoeuvre, position and assist the passenger transfer and seat the passenger | The ramp requires just one attendant to board a client. The stair-lift requires two attendants. |
| (b) Preboarding | Preboarding in a designated level area is recommended for both systems. |
| (c) Ease with which it can be moved about the terminal (operating environment) | Both systems can be moved on level ground or on moderately sloping smooth ground with very little effort. |
| (d) Effort/time required to transport device from storage to the platform area | Both effort and time are very moderate. |

(5) Accessibility

(a) Seat design

The transfer chair is an outstanding feature of our bus-boarding design. It is described fully in section 4.

(b) Device size/area remaining for passengers

Ambulatory passengers cannot board the bus while either of the two boarding devices is attached. However, this will not be a problem if prior boarding is done at a location away from the ambulatory passengers.

(c) Transfer time from when passenger begins to transfer into device chair until the passenger is seated into the coach

When an operational prototype is constructed, we expect that the transfer times will be approximately three minutes.

(6) Technical Requirements

(a) Power

Our present version of the stair-lift uses 110V AC from the terminal building.

(b) Manual override

There is no manual override on our full-scale mock-up of the stair-lift. However, there is a reliable mechanism to prevent the chair from moving in the event of a power failure, cable breakage, etc. It would be straightforward to put a manual override on the stair-lift.

(c) Lift/chair speed

This is constant.

(d) Selection of components

The stair-lift is mainly based on a commercial stair-lift system. The mock-up of the ramp was made from readily available Dexion steel and plywood.

(e) Pay load

250 lbs.

(f) Design load

N/A (This is a mock-up).

(g) Design life

N/A (This is a mock-up).

(7) Control System

(a) Control system features

In the event of a power failure, cable breakage, or slackening of cable, the system will stop without any slippage.

(b) Function of control panel

The original stair-lift control panel was retained for this mock-up version.

7.2 Specific Evaluation using Potential Clients.

Five disabled clients of the Rehabilitation Centre practised transferring from their wheelchairs to the transfer chair and back. Volunteers were brought into MC-9 buses using the two boarding systems. Both systems worked very well and only very minor problems were encountered. Two problems which were solved by modifying the design of the transfer chair are:

1. The original transfer chair did not have lateral leg restraints and this caused legs of paraplegic users to fall open with the danger of injury. This was solved with the addition of leg restraints which are shown in figure 1.
2. The original seat-belt anchoring systems on the transfer chair got in the way of clients transferring from their own chairs. This problem was also corrected.

The other problems encountered, which will have to be corrected in the next version of the boarding systems, are as follows:

- i) With the present transfer chair, the height adjustment can only be done from the back. This can present a problem once the transfer chair has been brought to beside the first row of passenger seats. The attendant is then in front of the transfer chair, and unable to adjust the height to allow for a level or high - to - low transfer. Raising the transfer chair to the correct height before boarding the bus would be risky as it might cause the client to hit his or her head when going through the bus doorway. Thus, the transfer chair would have to be re-designed so that the height could be adjusted either from the front or the back. This modification would be quite minor.
- ii) The final version of the ramp should be re-designed so that it can be opened in a shorter time than the approximately five minutes taken by our current version.
- iii) The commercial stair-lift system we used had a motor weighing approximately 100 lbs. More importantly, the whole system was very sensitive to voltage fluctuations. For the testing, we had to bring our gasoline-powered generator which produced a well-regulated voltage. This would be a very undesirable situation in regular use. It could be rectified by purchasing a stair-lift system which is less affected by voltage changes.
- iv) A manual override would have to be added to the stair-lift, so that the client could be de-boarded in the event of a power failure. This would be a straightforward addition to the present stair-lift design.

8. COST ESTIMATES FOR PRODUCTION UNITS

An estimate of production costs for the station-based bus boarding systems is very difficult to make. Engineering prototypes were constructed only to determine the efficacy of the designs. These prototypes function in the same way that production models would function and have the same general physical shape. However, several modifications would be required to the designs in order to improve the safety, aesthetics and ease of fabrication of these devices. Consideration must also be given to the number of units that would actually be produced and what economies of scale could be realized. Obviously, the per-unit-cost of producing 10 units would be much higher than for producing 1000 units. For larger scale production, machine set up costs are averaged over a greater number of units and more efficient fabrication techniques can be implemented. For example, the service ramps on the stair glide system could be pressed out of a single sheet of aluminum, rather than being made up of smaller sections of sheet aluminum held together by nuts and bolts. These production techniques, however, are not feasible for small volume production.

8.1 Stair Lift System

The following is a breakdown of the cost of producing a single stair lift unit, identical to the prototype. From these numbers, an extrapolation can be made into the costs of further production. (All costs are in Canadian dollars.)

Materials:

Aluminum	\$ 600.00
Brass	50.00
Stainless steel	100.00
Nylon	100.00
Steel	50.00
Threaded rod	100.00
Hardware	500.00

Other Items:

Stair Glide™ motor & controller	\$ 6,000.00
Casters/brakes	500.00
Electronics	500.00

Labour:

12 weeks (450 man-hours @ \$50/man-hour)	\$ 22,500.00
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Total: \$ 31,000.00

The above estimate is extremely labour intensive. Large scale manufacturing of the device would decrease the amount of labour required by using larger machinery. Of the materials required, the Stair Glide™ motor and controls are the largest cost item. Substitution of a standard motor and a custom designed controller would decrease this cost to under \$1000 after development costs had been absorbed.

To move from the engineering prototype to a production prototype and, finally, to a production unit, would require two to three months of further development. Once completed, efficient production could begin. An estimate of per-unit-cost at this point depends greatly on the number of units produced. The cost of materials would be reduced slightly in large scale production, probably being fixed at around \$2500-\$3000. Above this is labour and capital costs which would likely bring the cost per unit to between \$6500-\$10000, depending on the number of units being produced, with 20 being a minimum.

8.2 Ramp Boarding System

An estimate of the cost of production of the ramp boarding system is even more difficult. Dexion steel was used to build the prototype because it was a very iterative process. Dexion construction allows for many design changes without extra expenditure. A production model would not contain any Dexion steel, but would be constructed of solid materials, probably aluminum angle. The cost of the prototype ramp was \$2500 in materials and 375 man-hours of labour at a cost of \$16,875. This amounts to a total cost of \$19,375.

A production prototype of the ramp would require a complete change of materials and, therefore, a complete re-analysis of the structural base. This would entail several months of further development with special emphasis on safety, aesthetics and production techniques. In the end, the per-unit-cost of production would likely fall within the range of \$5000-\$9000, depending on the number of units produced.

8.3 The Transfer Chair

The transfer chair, common to both boarding systems, uses a seat lift device from a barber shop chair. Customizing this part to fit onto the transfer chair platform requires removing it from the chair base and specially machining it. This job requires a full week of labour (37.5 man-hours). Total costs for the transfer chair are listed below:

Materials:

Barber chair	\$ 400.00
Aluminum	80.00
Stainless steel	100.00
Nylon	10.00
Seat belt	10.00
Casters/brakes	500.00
Seating material	50.00
Hardware	50.00

Labour:

3 weeks (120 man-hours	\$ 6,000.00
@ \$50/man-hour)	
Total:	\$ 7,200.00

In large scale production, the transfer chair could be produced for under \$3000, however further development of about two months duration would be required to reach this stage.

9. PROPOSED FULLY-PORTABLE BUS-BOARDING SYSTEM.

A 1:8 scale model was constructed of the proposed portable boarding system. Some of the components for this model were constructed under a previous contract with Transport Canada - No. T8080-6-2663/01/FT. However, this specific boarding concept is a new one and was developed based on our experience with the present contract. The new bus-boarding system is shown in figure 11. The model has 6 separate components all of which can be stored in the luggage compartment of a bus without taking up much room. The components (from left to right) are as follows:

1. The foldable transfer chair (which in reality will be smaller than the model suggests).
2. A platform to go on top of the forks of the fork-lift.
3. A portable and manual fork-lift
4. A ladder which can be used by the attendant to climb into the elevated fork-lift and push the transfer chair into the bus.
5. A small ramp to bring the transfer chair from ground level to the lowest level of the fork-lift.
6. An interface platform which will be placed on the bus stairs.

Outline of Bus-Boarding Procedure:

1. The interface platform is placed on the bus stairs (fig. 12).
2. A platform is attached to the forks of the fork-lift (fig. 12).
3. The fork-lift is placed at the open doorway, facing the same direction as the bus (fig. 12).
4. The disabled subject transfers to the transfer chair.
5. The attendant brings the transfer chair onto the fork-lift platform, using the small ramp (fig. 13). The transfer chair is secured to the platform.
6. The fork-lift is raised to the level of the interface platform (fig. 14).
7. The attendant uses the ladder (fig. 14) to climb up to the fork-lift platform and push the transfer chair (with the subject) onto the transfer platform and to the aisle of the bus.
8. When the transfer chair is brought beside the first row of seats, a level transfer is made.
9. All of the equipment can be stored in the luggage compartment of the bus.

The procedure for de-boarding will be the reverse of the boarding procedure.

Features and Advantages of this Bus-Boarding System:

1. All of the components will fit in the luggage compartment of the bus without taking up much space.
2. All of the components are light enough to be lifted by a single attendant. The heaviest component (the fork-lift) is shown being lifted by a technician in figure 15.
3. The elevation of the fork-lift is manually powered.
4. The complete procedure can be performed by a single attendant.
5. Since the fork-lift does not have to be moved while the patient is on it, this boarding system is quite tolerant to rough or uneven ground.

To evaluate this boarding system, it would be necessary to build a full-scale operational mock-up. This would enable complete evaluations to be performed, just as they were performed in the present contract

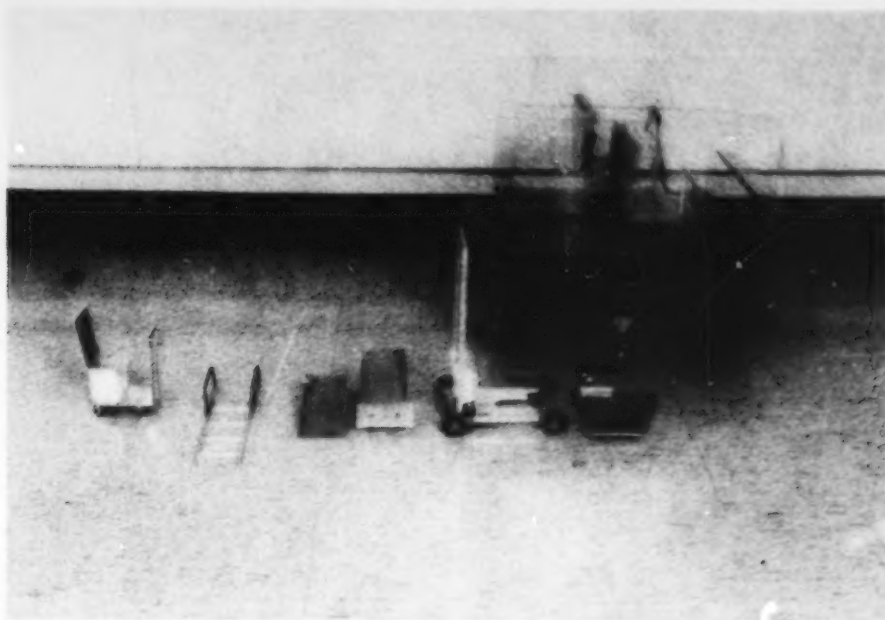


FIGURE 11 - MODELS OF PORTABLE BUS-BOARDING COMPONENTS

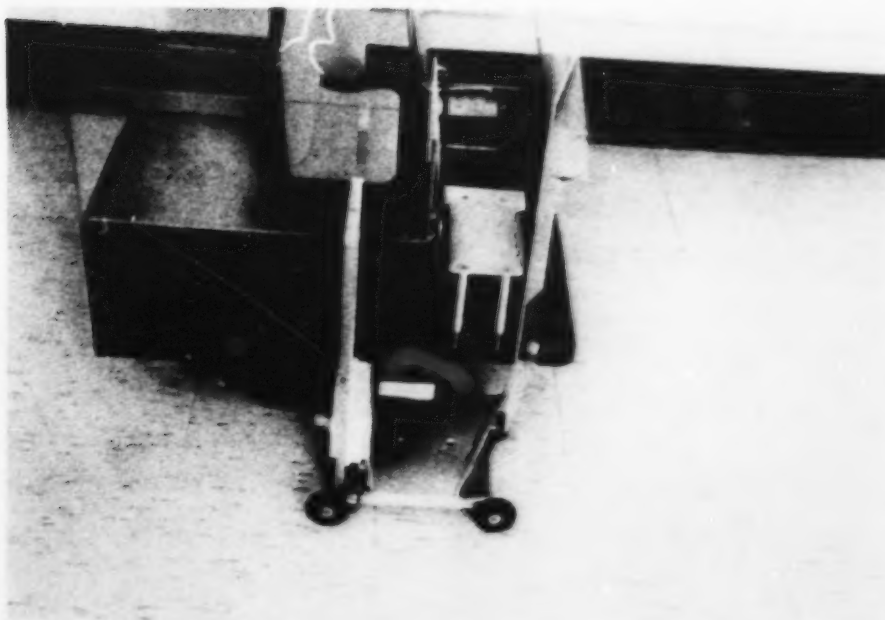


FIGURE 12 - FORK-LIFT AND INTERFACE PLATFORM



FIGURE 13 - START OF BOARDING PROCEDURE



FIGURE 14 - BUI-BOARDING IN PROGRESS

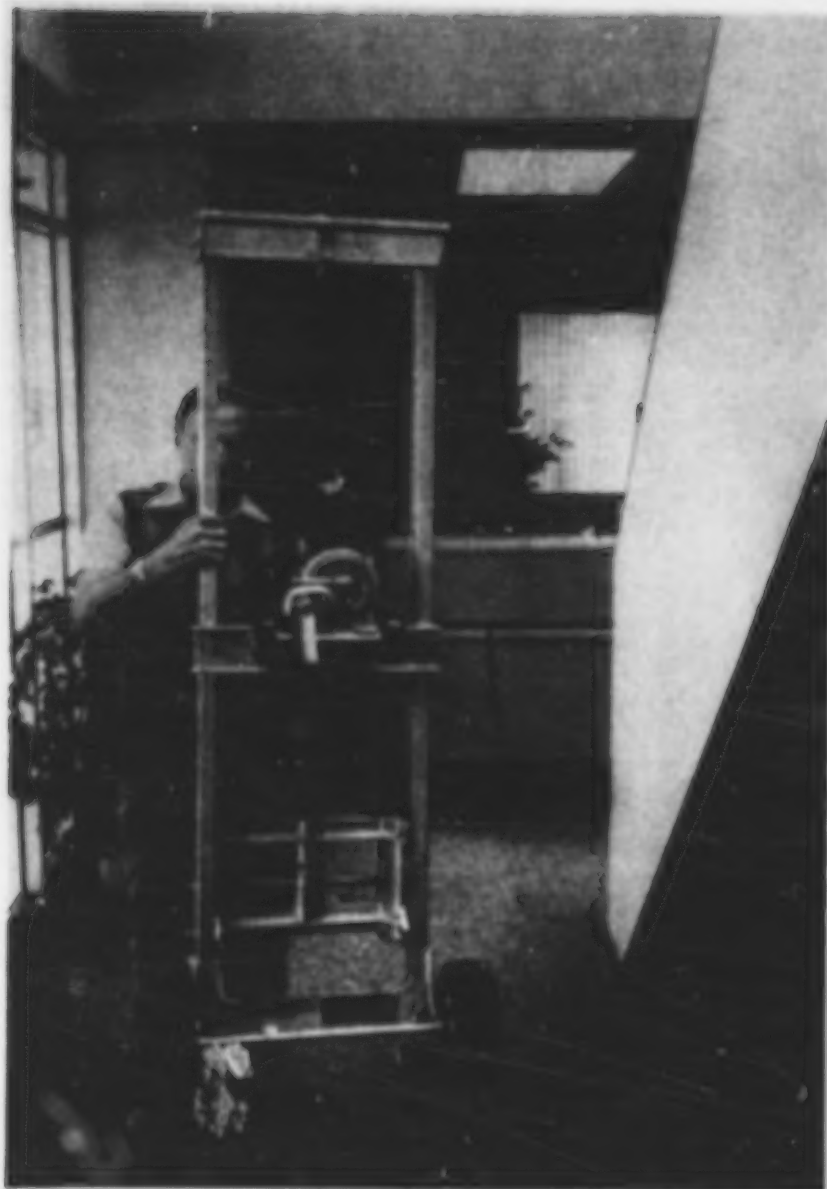


FIGURE 15

FORK-LIFT BEING LIFTED UP

10. BUS MODIFICATIONS NEEDED

An important feature of our designs is that the whole boarding process will require just one modification to some bus models and none at all to the newer MC-10 buses. The modification needed is to enable the armrests on the aisle sides of the first row of seats to flip up. No modifications are needed to: the door opening angle, the permanent lift attachment fittings, the safety bar, or the modesty panel.

With the seat arms modified when needed, the only limitations to boarding disabled persons into buses arise from the dimensions of the entrances of buses themselves (as related to the dimensions of prospective users) and not from the boarding system we have designed.

It must be kept in mind, of course, that appropriate restraint systems will be needed in the bus seats once the disabled persons have been boarded. Since this was outside of the range of the present contract, it is not addressed in this report.

11. CONCLUSIONS

This project was performed on schedule and has achieved its desired goals. Full-scale working mock-ups of the two bus-boarding systems were designed and constructed. This enabled us to eliminate any guess-work or suppositions from our evaluations as would have been inevitable if we were confined to using non-operational mock-ups. Arising from our studies, investigations, and tests, we have come to the following conclusions:

- i) The strategy of constructing a special transfer chair which can be brought into the bus and down the aisle to the first row of seats, is very viable and has significant advantages over other bus-boarding strategies.
- ii) The ramp which is used to bring the transfer chair to the level of the aisle of the bus, has the advantages of: simplicity, independence from external power, and it requires only one attendant. However, the size of the ramp (even when folded up) hinders its usability and usefulness.
- iii) The stair-lift boarding system works very well so long as external power is available. It is more compact than the ramp, but neither small enough nor light enough to be carried on the bus for use in emergency situations. The fact that the stair-lift requires two attendants for its operation, may present problems under certain circumstances.
- iv) To board or de-board disabled travelers in emergency circumstances occurring away from a bus terminal, a third boarding device should be designed. This is described in section 9 of this report. The concept was originally proposed as part of our earlier contract (serial no. T8080-6-2663/01/PT). This system would use a manual fork lift which could be collapsed and stored compactly in the luggage compartment of the bus. It would require a special compact version of the transfer chair, so that it would not take up too much space in the luggage compartment of the bus.
- v) The two systems we tested are now ready to go to the "operational prototype stage". This would involve a few improvements to the design based on the tests we have performed, and the specification of different materials and components. For example, it was necessary that we use Dexion steel angles for our original mock-up of the ramp. It made it easy for us to make design changes. However, Dexion is inappropriate for an operational prototype, since fingers can get caught in the holes and this could cause injury. The stair-lift system would have to be changed to use a motor which was less affected by voltage fluctuations. However, shifting from our full-scale mock-ups to operational prototypes would not be a major endeavour, since the operational feasibility has already been established.

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12. RECOMMENDATIONS

Arising from the performance of the contract entitled "Design of Two Station-Based Boarding Systems for Intercity Buses", the following recommendations are made:

- 1) Because of the success of the operational mock-ups, this work should proceed to the design and construction of a few operational prototypes. These operational prototypes could be tested in actual use at various bus terminals throughout Canada. The staff of the Department of Rehabilitation Engineering at The Rehabilitation Centre in Ottawa have the expertise and experience needed to design and construct the operational prototypes.
- 11) A truly portable bus-boarding and de-boarding system should be designed and constructed, so that it can be carried on a bus for unexpected or emergency use between scheduled stops. Such a boarding device was originally suggested by the Department of Rehabilitation Engineering at The Rehabilitation Centre in Ottawa, under an earlier contract for Transport Canada. It was further developed by us and is described in detail in section 9.0. Personnel in this department have the experience and the expertise for the performance of this work.